Spring 2008
Industry Study

Final Report
Electronics Industry

<u>The Industrial College of the Armed Forces</u>
National Defense University
Fort McNair, Washington, D.C. 20319-5062

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ELECTRONICS INDUSTRY STUDY 2008

ABSTRACT:
America has long enjoyed worldwide leadership in the electronics industry. Such leadership has conferred tremendous economic and security benefits, however, today large segments of the semiconductor value chain have moved to Asia, drawn by foreign government incentives. The United States risks losing leadership in this critical industry unless immediate proactive policy measures are adopted, including support for education and R&D through full funding of the America COMPETES Act, tax and R&D incentives for American-based semiconductor companies, and the recruitment and retention of global engineering talent through the modification of the current H-1B visa program.

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PLACES VISITED AND MEETINGS

Domestic:

National Capitol Region
Department of Commerce (ICAF, Seminar Classroom)
Woodrow Wilson Center (ICAF Seminar Classroom)
National Academies of Science (ICAF Seminar Classroom)
Rochester Electronics (ICAF Seminar Classroom)
Semiconductor Industry Association (ICAF Seminar Classroom)
Texas Instruments (ICAF Seminar Classroom)
Updata Venture Capital (ICAF Seminar Classroom)

Office of U.S. Senator Lamar Alexander, R, Tennessee (Washington, DC)
Office of U.S. Senator Joseph I. Lieberman, I, Connecticut (Washington, DC)
International Business Machines (IBM) (Washington, DC)
Micron (Manassas, VA)
National Institute of Standards and Technology (NIST) (Gaithersburg, MD)
National Security Agency (Fort Meade, MD)
Northrop Grumman (Linthicum, MD)
Semiconductor Research Corporation (Washington, DC)
Semiconductor Equipment and Materials International (Washington, DC)
U.S. Naval Research Laboratory (Washington, DC)
Virginia Semiconductor (Fredericksburg, VA)

New York State
International Business Machines
- Yorktown Heights – Watson Research Center
- Fishkill – 300mm Fabrication Plant
- Poughkeepsie – Customer Solution Center, Large Systems Manufacturing

Nanotechnology Research Center
- Albany

California – Silicon Valley
Advanced Micro Devices (AMD) (Sunnyvale)
Applied Materials (Sunnyvale)
Defense Micro Electronics Activity (Moffett Field)
Electronic Design Automation Consortium (Sunnyvale)
- Cadence, Mentor Graphics, Synopsys

Intel (Santa Clara)
Stanford University (Palo Alto)
Tessera (San Jose)
Xilinx (San Jose)

International:

Taiwan
Advanced Semiconductor Engineering Company (ASE)
American Institute in Taiwan (AIT)
American Chamber of Commerce, Taipei
Etron Technology, Inc.
Industrial Technology Research Institute (ITRI)
Macronix International Company
Nanya Technology Company
Semiconductor Industry Promotion Office (SIPO)
Taiwan Semiconductor Industry Association (TSIA)
Taiwan Semiconductor Manufacturing Company (TSMC)
United Microelectronics Company (UMC)

People's Republic of China

Shanghai
Semiconductor Manufacturing International Corporation
U.S. Consulate General

Beijing
Chinese Semiconductor Industry Association
IBM China Research Lab
Lenovo Group
Oracle-Asia Research and Development Center
Semiconductor Industry Association, Beijing
U.S. Information Technology Office

INTRODUCTION

This report summarizes the findings and conclusions of the Electronics Industry Study Seminar at the Industrial College of the Armed Forces (ICAF), Class of 2008. It examines a critical sector of the United States' economy – the electronics industry – and focuses on the semiconductor field within that industry. It is a culmination of a focused series of classroom and field study seminar meetings with industry, government, and academic leaders. Seminar meetings included discussions and meetings in the Washington, DC area, as well as field studies in New York State, California's Silicon Valley, Taiwan, and the People's Republic of China. The Electronics Industry Study assessed many perspectives in examining the semiconductor industry, including current conditions, the industry's outlook, industry challenges, major issues, and U.S. Government goals, objectives, and policy recommendations.

The semiconductor industry has driven United States growth and productivity since its birth in Silicon Valley, California fifty years ago. It is currently the second largest U.S. export industry, with 2007 total exports of over $52 billion.[1] It employs over 232,000 Americans, providing well-paying jobs that generate over $118 billion in annual revenue.[2] The industry is a key enabler for other industries, providing breathtaking and monumental advances across the global economy. Today, knowledge workers in industries as diverse as finance, biotechnology, and agriculture are vastly more productive and effective due to ever more powerful semiconductors. Electronics have historically provided the United States' military with a decisive technological edge, and they continue to play a critical part in facilitating the U.S. military's mission to safeguard America.

Table 1:
Industry Challenges and Major Issues

Industry Challenges	Major Issues
Continuing Moore's Law	Trusted Foundries and the Threat of Substitution
Educating the Workforce	Security Implications of Offshore Fabs
Supporting Semiconductor R&D	Are Semiconductors a National Priority?
Protecting Intellectual Property	

This report defines the semiconductor industry (including its value chain), examines current industry conditions, and reviews the industry outlook. It analyzes current challenges and major issues facing the industry (as outlined in Table 1), and provides U.S. Government policy recommendations that address those challenges and issues, with the intent of sustaining the long-term prosperity of the U.S. semiconductor industry for national benefit.

THE INDUSTRY DEFINED

The semiconductor industry is the driving force behind the overall electronics industry. It began with the invention of the integrated circuit (IC) or "chip" by Jack Kilby of Texas Instruments (TI) in 1958[3]. Originally fostered by the demand from government and military applications, today the electronics industry is driven by the worldwide consumer electronics market, especially the games industry. Growth in today's nearly $280B annual industry is mostly attributable to the explosive growth in demand for personal computers, communications devices, MP3 players and digital televisions. Additionally, the global production of semiconductors continues to be a critical driving force of innovation in world economies, integral to quantum advances in productivity in nearly every business sector, from computing to healthcare, through the ubiquitous employment of electronic devices. Semiconductors are used in many industries to enhance productivity and they remain important in the functioning of most modern military systems used in a network-centric environment.

The primary activities of the semiconductor value chain are: **Design**, **Mask Generation**, **Fabrication**, **Testing**, and **Assembly**[4] as shown in **Figure 1**:

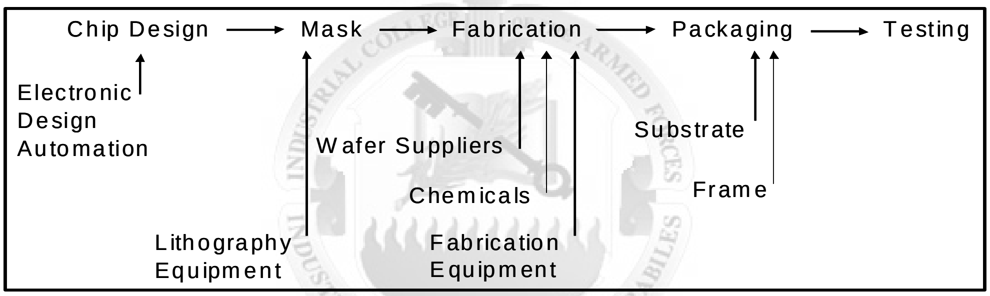

Figure 1: The Semiconductor Industry Value Chain[5]

The economic characteristics of each process step differ significantly. Chip design is skill-intensive, and requires expensive Electronic Design Automation (EDA) software. Mask generation, a process in which master circuit designs are transferred to glass masks via specialized photolithography equipment, is also very skill and capital-intensive. Mask plates can cost over $1M apiece, and, depending upon the complexity, advanced circuits can require multiple masks. Fabrication requires a huge fixed investment – currently about $3 billion – to build a foundry (called a "fab") that must be built to extreme cleanliness standards and support a variety of expensive equipment.[6] Assembly and packaging also require expensive equipment, but the overall costs of plant and equipment are much lower than for the fab, as are the average skill requirements.[7] Overall, worker skill requirements decrease down the value chain – design is more skill-intensive than fabrication, which is more skill-intensive than packaging and testing.[8]

The electronics industry's center of gravity is an "innovative ecosystem" that ideally co-locates world-class academic institutions (performing basic research and development) with venture capital institutions and leading IC design and production companies. This innovative ecosystem allows cutting-edge technologies and capabilities to transition quickly from academia to the commercial marketplace and provides enormous competitive advantage for its host country. The United States has historically led the development of an innovative IC ecosystem. However, that leadership is being challenged dramatically by foreign competitors as many of the higher segments of the semiconductor industry value chain move overseas.

CURRENT CONDITIONS

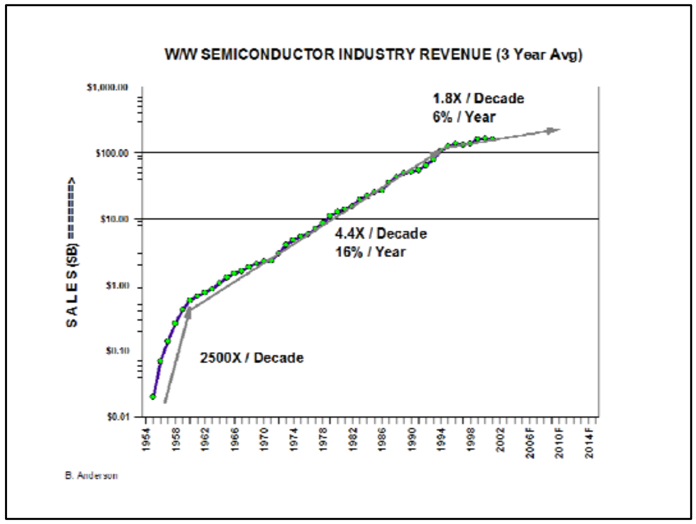

Figure 2:
Worldwide Semiconductor Sales

The semiconductor industry has grown at an average rate of over 18% over the past three decades.[9] This is a rate six times that of the U.S. economy at large; in fact, an astonishing 50% of the growth of the U.S. economy can be attributed to the productivity gains achieved by applying information technology to business processes throughout American industry.[10] Of course, semiconductors are at the heart of IT. This economic growth has fueled even greater demands for less expensive yet more powerful semiconductors, driving continued growth in the semiconductor industry.

However, despite this success, today the semiconductor industry faces challenges. As shown in **Figure 2**[11], although revenue growth has continued, the annual rate of growth has slowed to 6% in the last decade. Several factors have contributed to this "leveling-off" of profitability.

Moore's Law and the Costs of Keeping Up

In 1965, Gordon Moore observed that innovation effectively doubles the transistor capacity (and the inherent processing power) of a single integrated circuit "about every two years."[12] The price/performance ratio enabled by Moore's Law has successfully driven progress in the semiconductor industry, providing a roadmap for circuit engineers and designers to consistently increase performance and reduce the cost of semiconductors. The Semiconductor Industry Association (SIA) charts semiconductor progress via the International Technology Roadmap for Semiconductors (ITRS), which provides a 15-year outlook on major semiconductor industry trends. As such, it serves as a good guide for semiconductor manufacturers, suppliers of equipment, materials, and software, providing clear targets for researchers in the out years."[13] However, while semiconductor feature sizes continue to shrink, the fixed costs inherent in designing and producing them continue to rise.

Increasing Fixed Costs of Scaling. Continued progress on the path predicted by Moore's Law has presented numerous physical and material challenges. The challenge of electrical resistance in ever-shrinking aluminum wires was met through the introduction of copper wiring.[14] Subsequently, the challenge of overcoming circuit power leakage in the substrate material was met through the introduction of solutions like strained silicon, silicon on insulator, and low-K dielectric technologies. Technically-advanced solutions have come through increasingly expensive research and development at every level of the semiconductor value chain. Each level must accommodate these new advances in technology; equipment must be modified or replaced, and new processes researched, developed, and implemented. The result is that the fixed costs associated with producing leading edge semiconductors have steadily increased.

***Increasing Fixed Costs of Manufacturing*.** Innovations in manufacturing processes must keep pace with Moore's Law. As semiconductor feature sizes have continued to shrink, the precision of manufacturing equipment has proportionally increased. Capital expenditures for manufacturing, clean rooms, and more sensitive measuring tools for quality control have risen. To mitigate increasing costs through higher product yields, the industry has adopted larger wafer sizes in the manufacturing process. The industry has largely transitioned to a 300mm silicon wafer, achieving much higher yields than the previous 200mm standard. Such scaling and manufacturing innovations have made semiconductor manufacture increasingly capital-intensive.

The high capital investments required to build a leading edge fab are a barrier to entry for most semiconductor firms. Higher capital costs can only be supported through higher production quantities, which can be independently supported by only the largest volume semiconductor firms. The impacts of this barrier to entry are threefold: first, it results in fewer fabs being built which impacts the entire semiconductor ecosystem; second, it spawns an ever-increasing competition from nations and states to locate leading edge manufacturing sites within their borders, and third, it created a new kind of firm – the "fabless" IC producer.

An International Fight for the Foundry

The competition between states and nations to host leading-edge fabs has become increasingly intense. This competition has spawned government grants, tax incentives and reduced tariff and import restrictions. There are also market forces driving U.S. semiconductor manufacturing offshore. As overall electronics manufacturing has moved away from the United States[15], this market pull has attracted semiconductor production out of the United States so that manufacturers can produce electronic device components for efficient assembly overseas. Incentives such as aggressive grants and tax relief offered by foreign governments combine to produce an overwhelming force leading to the significant off-shoring of semiconductor manufacturing. **Figure 3** illustrates the net cost of building and operating a semiconductor fab in the United States compared to the construction and operation costs of establishing an equivalent fab overseas.[16] On average, the 10 year costs of building and operating an overseas fab are 25% lower than an equivalent facility in the United States. The difference is primarily caused by overseas tax and capital grant benefits, rather than by labor rates (per conventional wisdom). As foundries move overseas, they break away from U.S. design firms and the remainder of the semiconductor ecosystem. They then develop local ecosystems across the value chain. Ultimately, the same forces that moved these fabs overseas have a tendency to move the higher-end semiconductor value chain overseas with them.

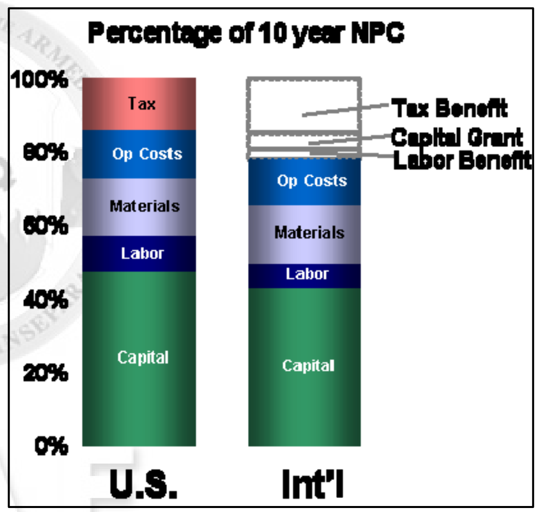

Figure 3:
Cost of U.S. vs. International Fabs

Key Companies in the Global Semiconductor Market

The top 25 semiconductor companies are mainly located in the United States and Asia. Intel dominates the semiconductor market, with 2007 revenues of almost $34 billion, accounting for 13.3% of the market[17]. TI today ranks third, behind Samsung of South Korea. Intel's closest competitor in the chip market, Advanced Micro Devices (AMD), lost more than 21% of revenues in 2007 and may lose its top 10 position in the near future.[18] The biggest winner of 2007 is Japanese Sony, which increased its revenues by more than 55%. Another notable increase is seen by German Infineon Technologies, which has spun off its memory business of Quimonda, ranked number 16 in the 2007 semiconductor market.

OUTLOOK

A Continued Pull of the U.S. Semiconductor Value Chain to Asia

The three key regions that are driving semiconductor design and manufacture (and their ultimate assembly into electronic devices) are the United States, the Asia-Pacific region, and Europe. In Asia-Pacific, the largest semiconductor players include Japan, Taiwan and China; in Europe, Germany, France and England are the most significant.

Foreign Tax Policies are a Magnet Pulling Capacity Offshore -- Comparative Taxes/Incentives

U.S.	❖ 35% corporate tax rate ❖ Various state-level incentives
ISRAEL	❖ Up to 20% capital grant ❖ 10% tax rate – 2-year tax holiday
CHINA	❖ 5-year tax holiday ❖ After holiday, ½ normal rate for next 5 years
MALAYSIA	❖ 10-year tax holiday
Taiwan	❖ 5-year tax holiday and other incentives ❖ Taiwan chip firms have reported higher net profitability *after* rather than *before* taxes.
IRELAND	❖ 12.5% corporate tax rate

Figure 4:
Comparing U.S. and Foreign Corporate Tax Policies

The earliest offshore investment in chip assembly was made in 1961 by Fairchild Semiconductor in Hong Kong for the assembly of discrete transistors.[19] Afterwards, local Asian firms started offering contract chip assembly services to US-owned plants.[20] Since the early 1990s, Taiwan has steadily increased its semiconductor industry and today has market share of 7%. Currently, the top 10 assembly contractors, with about 70% of total contracting revenue, are all Asia-based.[21] Semiconductor production and assembly has increasingly shifted to Asia due to favorable government incentives such as research consortiums, workforce education programs, tax holidays, and other tax incentives.[22] A study by the Semiconductor Industry Association (SIA) confirms that "the biggest cost differential between locating a fab in the United States versus overseas is not the cost of equipment or labor, it is foreign tax policies"[23] These incentives are estimated to yield savings of $1B per fabrication facility construction over a 10 year period.[24] These overseas government subsidies help firms to mitigate risk and investment in an extremely competitive economic environment. **They create an unlevel playing field for U.S. semiconductor manufacturers, who must move facilities to Asia in order to remain competitive**.

There are some positive benefits to offshoring. Reduced costs and the flexibility provided by offshore design centers have allowed new entrants and some incumbents in the U.S. to maintain

their competitive advantage despite the rising cost of the typical chip design.[25] The lower costs due to offshoring have also translated into increased consumer markets worldwide.

However, the high-value end of the semiconductor ecosystem is agile, and will tend to reorganize around the leading edge fabs in order to maximize innovation by reaping the benefits of symbiotic partnerships and collaboration, especially if academic or government-sponsored research institutions are similarly co-located as a supporting innovative ecosystem. Recently, higher-value activities on the U.S. semiconductor value chain have moved abroad, such that some manufacturing capabilities including photolithography (with complex optics and mask production equipment) are no longer available from U.S.-based firms. Unless the United States can pass legislation to reduce some of the highest corporate tax rates in the world[26] (as shown in **figure 4**), the bias towards moving increasingly-higher levels of the semiconductor value chain overseas will continue. For U.S. firms to remain competitive, federal and state governments must consider similar tax incentives and policies that make U.S. business more profitable than overseas markets. Additionally, U.S. companies must invest in R&D and strive to maintain an innovative, highly-educated workforce in order to set the pace of the market.

The United States

The United States semiconductor market is expected to steadily grow over the next five years, based on a historical Compound Annual Growth Rate (CAGR) of 9.9% for the period of 2003-2007, and generated total revenues of $47.2 billion in 2007. Integrated circuit sales drove the largest revenue growth in the U.S. semiconductors market with sales of $45.9 billion. Market growth is forecast to continue at a slower pace (indicating a maturing market), with an anticipated growth rate of 5.5% estimated through 2012, which will drive the market value to $62B. The United States generates 19.4% of the global semiconductors market, with Intel Corporation generating 11.3% of total U.S. sales. Underscoring the interrelated nature of the electronics business is the relationship between U.S. semiconductor exports and electronics imports. While the U.S. currently enjoys a surplus of semiconductor exports over imports, it also has a large deficit in the electronics sector, with devices containing U.S. chips returning to the U.S as finished goods.

The Asia Pacific Region

The Asia-Pacific semiconductors market is expected to experience strong growth through 2012, based on sales of $147.2 billion in 2007, and a CAGR of 11.2% for the period 2003-2007[27]. As in U.S. sales, the majority of sales are attributable to ICs, which represented over 80% of revenue. Market growth is expected to slow to a rate of 10% through 2012, driving sales to $243B. Asian countries (notably China and Taiwan) are likely to continue to pour significant government investment into developing semiconductor manufacturing capability. Fabrication plant construction is often subsidized by these country's governments, and "clustering" strategies of co-locating suppliers, producers, designers and academia have proven effective in producing high quality semiconductors at low prices. Low costs have additionally attracted business development from overseas, including many U.S. electronics firms. Foreign and government investment will continue to promote Asian semiconductor industry growth. Japan accounts for over 36.6% of the Asia-Pacific semiconductors market by value, with the growing Chinese market closing the gap with nearly 29% of regional revenues. Notably, China, as a final assembler of electronics devices, is importing semiconductors at an increasing rate, with the U.S. (primarily Intel Corporation) leading the growth.[28] Asia Pacific growth and market share will likely continue to grow.

The European Region

In the Europe region, Germany has been the semiconductor market leader, with France and England as the next most significant contributors. Germany generated total revenues of $15.1 billion in 2007, with a CAGR of 2.1% for 2003-2007. England and France grew 3.5% and 2.7%, respectively, over the same period, to reach respective values of $7.9 billion and $4.1 billion in 2007[29]. Germany's semiconductor market is forecasted to grow by 3% to a market value of $17B by 2012. Comparatively, the UK and French markets will grow by 2.7% and 2%, respectively, over the same period, to reach respective values of $9.1 billion and $4.5 billion in 2012[30]. The European semiconductor market is again dominated by Intel Corporation and Samsung Electronics, with 18% and 14% respectively. Recently, in an attempt to build its own innovative ecosystem and capture more of the value chain, Europe has developed partnerships with semiconductor companies, universities and government, in order to foster innovation and share research and development costs. Further tax incentives and favorable business policies are attracting semiconductor manufacturing firms to European countries.

The Rise of the Fabless Semiconductor Firm

A growing semiconductor industry business model is the shift towards outsourcing the actual production of the chip. This shift towards semiconductor firms going "fabless" is another effect of the increasing capital intensity of semiconductor manufacturing. The Fabless Semiconductor Association (FSA) tracks what it has termed the $1 billion capital expenditure club – those firms capable of absorbing a $1B capital expenditure. As early as 2003, only 6 firms were able to make such an investment; in the 2 years prior, 10 firms had fallen out of this club[31]. To remain viable, semiconductor firms have embraced a fabless business model in which 75% of manufacturing processes are outsourced either to other Integrated Device Manufacturers (IDMs) or to pure play foundries[32] which focus only on the fabrication portion of the value chain. The growth of companies utilizing the fabless business model continues with mixed implications. The positive aspects of fabless firms are that they utilize excess capacity resident in IDM fabs, helping them remain viable; they also allow the fabless company to focus on innovation and the higher value-added portions of the semiconductor value chain. Fabless business also lowers the traditional barriers to entry which potentially yields greater innovation in the industry. However, there are also downsides to the fabless business model. Fabless firms become dependent upon the firm that owns the production foundry, possibly sacrificing proprietary intellectual property (IP) as part of the bargain. Fabless firms are also less attached to the foundry for conducting research and development, and are therefore limited by capabilities of the foundry in the conduct of desired research which could limit innovation. Additionally, the fabless model potentially creates "seams" in the semiconductor ecosystem which can limit the collaboration needed for successful innovation.

CHALLENGES

Continuing Moore's Law in a CMOS World

Today's semiconductors are produced using a Complementary Metal Oxide Semiconductor (CMOS) technology by adding successive layers of conducting, semiconducting, and insulating materials onto the etched surfaces of a silicon chip. This technology has been successful in improving performance and reducing costs as forecast by Moore's Law for the past 20 years, however, industry experts predict that chip designers will no longer be able to use CMOS technology to achieve Moore's law beyond 2020.[33] Nanotechnology has the potential to continue the record of success by deploying entirely different technologies. Nanotechnology involves building structures with very small particles at the atomic and molecular scales, where materials exhibit different physical properties, such as extreme conductivity, great strength, and elasticity. Researchers are now focused on leveraging a "bottoms-up" method for building nanotech components, which will use organic molecules or nanoparticles to build, "at the ultimate level of control, one atom at a time."[34] Scientists are also examining alternatives to traditional IC design that potentially use electron spin instead of charge to convey information in the logic circuit. Such breakthroughs rely upon the success of cutting-edge basic research and development now being conducted in universities and government labs; efforts such as those fostered through innovative public-private partnerships like the Nanotechnology Research Center in Albany, NY. Leadership in nanotechnology research is critical to retaining leadership in the semiconductor industry, as technological developments continue to shape the industry.

Educating the Workforce

The rapid pace of technological change and innovation in the semiconductor industry requires a skilled and educated workforce to ensure the viability of the industry's current technology and future innovations. Robust math and science education is critical as companies push manufacturing processes and research and development to the limit. However, recent indicators suggest that U.S. K-12 science and engineering education has not kept pace. In 2006, 51 percent of all masters degrees in electronics and electronic engineering granted by U.S. universities were awarded to foreign nationals, and 71 percent of all Ph.D. recipients in those fields went to foreign students studying in the United States. The U.S. potentially stands to gain from this "brain drain" from other countries, however, current US immigration policies limit the number of H-1B visas and create barriers for students who want to stay and work in the U.S. Recent trends show that if current US policies are not revised, many of the foreign students receiving advanced science and engineering degrees in the U.S. will be recruited by companies in other countries and the U.S. will lose the benefit of their knowledge and expertise. While returning students potentially serve as important resources for socio-economic development in their home countries, the U.S. workforce cannot participate effectively in a world that is increasingly shaped by science and technology without basic math and scientific literacy.

In order to retain a strategic lead in the international semiconductor industry, the U.S. must reinvigorate national efforts to stimulate and support the improvement of Science, Technology, Engineering and Math (STEM) education. It must find ways to keep foreign nationals who graduate from U.S. universities in the United States, where they can use their knowledge to support the U.S. semiconductor industry, and it must find ways to recruit and retain the brightest scientist and engineers from around the world in order to ensure that the U.S. semiconductor industry's "innovative ecosystems" remain successful.

Supporting Semiconductor Research and Development

The nature of the global semiconductor industry is highly competitive and driven by new product innovations. The fuel for the semiconductor innovation engine is a broad base of R&D which must be sustained over time. In 2007, the industry provided 233,000 highly competitive, high wage jobs and was able to invest heavily with $13 billion in capital equipment and $18 billion in R&D. With an average of 15 percent of revenue going back into R&D, the semiconductor industry is investing more than any other U.S. industry.[35] However, in 2005, Semiconductor Equipment and Materials International (a global industry association,) commissioned a R&D study that found a tremendous gap between what industry needs to spend to stay on track with the International Technology Roadmap for Semiconductors (ITRS,) and what the industry can afford.[36] The conclusion was that the semiconductor industry needs to be more targeted and effective in its R&D expenditures, but it can't make up the gap alone -- government must play a critical role in supporting basic research.

Overall, Federal R&D funding has decreased, leaving much of the funding burden on industry. Jacques S. Gansler (former Department of Defense Undersecretary for Acquisition, Technology, and Logistics) recently noted that there is a "troubling trend" in the U.S. government to move away from supporting early basic research (that supports technology breakthroughs) to instead funding only near-term development and procurement in support of immediate needs. Congress passed the America COMPETES Act in August of 2007, but it has yet to fully appropriate funding to support it. Congress needs to improve America's basic R&D posture by enabling industry and government institutions: first, by fully appropriating funds to execute the programs addressed in the America COMPETES Act, and second, by making the enhanced industry R&D tax credit permanent in order to increase incentives for business to invest in R&D over the long term.

Protecting Semiconductor Intellectual Property (IP)

The tremendous resources spent on semiconductor research and development result in a stream of new products that must be protected as Intellectual Property (IP). The impacts of globalization, narrower profit margins, and greatly increased competition in the semiconductor industry have highlighted the criticality of protecting IP, however, "the intangible nature of intellectual property and the worldwide inconsistency of standard practices create challenges for U.S. businesses wishing to protect their inventions, brands, and business methods in foreign markets."[37]

Violations of IP occur through stolen patents, trademarks, copyrights, and trade secrets – all of which can lead to the manufacture and sale of counterfeit products. Historically, the government has played an active role in semiconductor IP protection; the Semiconductor Chip Protection Act (SCPA) of 1984 was described as the "first significant intellectual property (law) created in over 100 years."[38] For the same reasons as in 1984, the U.S. government must remain vigilant in its efforts to protect the IP of U.S. semiconductor companies. The role of the World Trade Organization (WTO) is also vital to establishing important international benchmarks. Countries that fail to enforce IP at home result in a loss of significant IP investment and revenue by American companies and negatively affect the economy and gross domestic product of the United States. The U.S. government must seek aggressive action from the WTO for IP violations and apply strict penalties to those nations that continue to ignore the law. Additionally, semiconductor firms must evaluate the strategic environment and carefully weigh the IP risks and potential revenues when choosing their international business partners.

MAJOR ISSUES

Trusted Foundries and the Threat of Substitutions

Given the recent trend of migration of many phases of the semiconductor value chain (most notably foundry production) to Asia, there is concern about continued access to trusted ICs. Trustworthiness is the confidence that classified or key mission information, *"…contained in chip designs is not compromised, reliability is not degraded, or unintended design elements inserted in chips as a result of design or fabrication in conditions open to adversary agents.*"[39] Acutely linked with IC trustworthiness is the ability to provide assured sources of microelectronic components as necessary. Where and when foreign sources of supply are used, greater risks arise from counterfeit ICs, geo-political forces, and natural disasters.[40] Numerous military systems and programs ultimately require military-specific ICs that cannot be obtained from the commercial market. Given the environment of a declining US microelectronics manufacturing base and a severely diminished capability to persuade IC suppliers to manufacture chips for the U.S. government, there is a valid concern within the US defense community regarding the issue of access and trust with respect to semiconductors and the impact on national security.

The Trusted Foundry. One key strategy encompasses DOD's Trusted Foundry Program (TFP), which is designed to provide a source of high-performance semiconductors for sensitive defense and intelligence community applications by establishing "take or pay" contracts with leading U.S. owned and located IC manufacturers.[41] The initial contract, worth up to $600 million and currently signed with IBM as the only leading-edge IC manufacturer, provides facility security control up to DOD Secret; the capability to produce both classified and unclassified chips.[42] Recently, the TFP has been expanded to include companies throughout the microelectronics supply chain. As such, ten US companies have signed on to the TFP to provide older or other fab technologies and certification as trusted suppliers.[43] Since the program's inception, over 150 IC designs have been manufactured through the TFP for the U.S. Armed Services, the Defense Advanced Research Projects Agency (DARPA,) and the National Security Agency (NSA,) to include components for the Army's Joint Tactical Radio System (JTRS), the Navy's SPY-1 and Guidance Integrated Fuze (GIF) programs, the Air Force's Global Positioning System (GPS), and DARPA's Threat Engagement Analyses Model (TEAM) program.[44] The TFP was instituted as a short-term measure and the current contract is set to expire in 2011.[45] However, given the historical market volatility of the IC market, there is no real assurance that any commercial vendor will desire to engage in such a partnership in the future. With a requirement of roughly 50 to 60 new critical defense related microchips each year, the current contracted TFP production capability is unable to meet all trusted demand.[46] Thus, it is incumbent on acquisition contracts to critically identify what components require the extremely limited capacity that the TFP can provide, or for the DoD to increase funding for the current Trusted Foundry program to accommodate all requirements. The Trusted Foundry Program has proven moderately successful for DOD and the intelligence community in the short-term – trust and access have been assured for a few, comparatively small-batch critical components – but numerous other semiconductor needs must be met elsewhere, through arguably less secure methods.

Trust but Verify. As IC technology has moved abroad, the reality already exists that foreign-made integrated circuits are components on virtually every major US weapon system.[47] As modern DOD and intelligence systems commonly contain numerous ICs, the foreign chips actually used may not be the most sophisticated or critical, but any level of compromise to any device – intended or otherwise – would still impact system effectiveness. However, abstaining from foreign chips altogether is not an option. Given DOD's minimal global market influence, the United States will continue to depend on microelectronics developed abroad.[48] DOD's Defense Advanced Research Projects Agency (DARPA) acknowledges this dependence and is seeking ways to ensure the security of imported ICs through a program call "Trusted ICs." The central goal of the program is to develop procedures and techniques that can "trust but verify" components – whether after manufacture, or while awaiting IC packaging in another country, or just sitting on a maintainer's parts shelf years later awaiting use as a replacement.[49] "Verification" actions must take place along the total IC value chain, whether it deals with the validation of design software, detection of malicious additions to circuitry (the so-called "Trojan Horse"), or distinguishing any degradation of chip design features from original parameters. The challenges to develop such capabilities are formidable, as most design tools concentrate on ensuring functionality and not on detecting alterations or additions to circuitry.[50] However, future technological advances may provide methods to design better "tests for trust" into the very development of the chip itself. Also, chip designers could potentially concentrate on tamper protection technologies and even methods that may disguise the true function of the chip itself.[51]

Is it "Real"? Technically, a counterfeit semiconductor is any substitute or copy microelectronic circuit that is knowingly misrepresented as an IC as having "real"/intended design characteristics. Given the profitability of microelectronic circuits sales, counterfeit ICs are a big growth business.[52] US Customs and Border Protection and EU law enforcement entities have already seized more than 360,000 counterfeit ICs and network components bearing more than 40 different trademarks.[53] "A criminally profitable enterprise, it is estimated that counterfeiting accounts for more that 8% of the global IC trade and is equivalent to lost sales of as much as $20 billion dollars, and is estimated to grow by 2009." [54] A counterfeit IC can range from a copied imitation using substandard materials to a legitimate chip manufactured in an authorized facility that did not meet standards but was deceitfully recouped and sold as high-quality. Or, as a potential concern for US companies using foundry facilities offshore, counterfeit chips can take the form of unauthorized runs of extra ICs made and sold without approval. For DOD and the US government, counterfeit ICs have the same effect as any compromised chip: putting critical defense, communication and financial systems (and ultimately the people that depend on those systems) at risk. As a result, ensuring trust of the component supply chain is critical. Unfortunately, given the proliferation of counterfeit ICs in the industry, there is a high probability of tainted chips within the current supply structure. In addition, defense systems often maintain their legacy chip technologies for years beyond the normally short production runs typical of most ICs. Commercial IC vendors must respond to the market and retool for the next higher level of technology, leaving few choices for defense system suppliers charged with maintaining critical semiconductor components. In many cases, the required microelectronics may have become obsolete and no longer exist. In such extreme cases, the Trusted Foundry Program can be implemented for critical resupply, and chip verification

strategies previously discussed can provide trusted access for the supply chain. But the most effective approach to avoiding counterfeit chips is to purchase ICs directly from the original component manufacturer.[55] For a truly healthy, accessible and trusted supply chain to exist, it is imperative that DOD and other US government consumers of high-value chips adopt a long-term approach to system acquisition and life-time sustainment.[56] Strategies for the sustainment of critical components must be pre-planned well before system fielding in order to identify the critical supporting technologies required to manufacture and produce needed components. If a specific defense system requires critical ICs based on 90nm technology, it is imperative that defense suppliers note methods for sustained 90nm procurement or production (if necessary) before 90nm production is phased out by the original manufacturer. At the very least, the system should be aware of when such major movements will take place in order to be positioned to make final "lifetime buys." Assured and trusted access also provides a hedge against non-industry factors (e.g. natural disasters, geo-political influences, etc.) that can shock the supply chain at any time.

Trusted Foundry Recommendations. The Department of Defense has initiated several measures to increase and assure trust and to stem negative trends (including the TFP, chip verification procedures, and trusted suppliers), but more must be done to ensure long-term success. The long-term question of DoD access to trusted leading-edge U.S. IC manufacturing capability is whether U.S. technical leadership in the IC industry is still available if the majority of production continues to slip overseas. A reversal ofo that trend requires significant U.S. government policy commitment and direction.

Off-shore Semiconductor Fabrication and National Security

Outsourcing can be defined as "the transfer of control of a process or product to a supplier that is better equipped to perform a specific business function"[57] with comparative advantage. Much attention has focused on offshoring of semiconductor fabrication services overseas. "Offshoring" refers to a company's purchase of services (such as manufacturing or software programming) from other countries where these activities were previously accomplished domestically. IT semiconductor manufacturing has a long history of offshoring its manufacturing operations. The U.S. semiconductor industry began offshoring labor-intensive manufacturing operations in the 1960s and expanded in the 1970s and 1980s to increasingly more complex activities including wafer fabrication, some research and development, and basic IC design work. Semiconductor assembly and testing was the first function to move to Asia, followed by fabrication, and more recently by some design operations.[58]

Strategic Security Considerations. There are several strategic security considerations associated with the offshore manufacturing of semiconductors. Businesses will naturally seek to maximize profits and take advantage of overseas environments with lower production costs, more lax environmental regulations, fewer employee benefits and lower salaries for skilled foreign workers.[59] On the national level, outsourcing can create fewer U.S. professional and technical opportunities and fewer tax revenues to support essential government services. In the long term, the U.S. risks losing high-end research and design talent and semiconductor specialty design jobs, because higher-skilled workers tend to locate with the semiconductor industry value chain as it moves to Asia.[60] As fabs move to advanced levels of technology, the ability of the

U.S. to recreate its semiconductor manufacturing capability becomes exponentially more costly. Strategically for policy makers, this means an increased dependence on other nations to supply critical manufactured defense parts and equipment. U.S. national leadership of semiconductor technology appears to be threatened by offshore fabrication trends that can pose long-term national security vulnerabilities.

This dramatic change is not in the best interests of the Department of Defense (DoD) and Department of Homeland Security. Semiconductors are the standard building blocks for the global information grid to support computers, communications and military information and data exchange. The semiconductor industry provides much of the technology for U.S. military communications that are critical for command and control and effective leadership. Research notes that military and intelligence reliance on semiconductor ICs built offshore are not an acceptable national security option.[61] The massive shift from U.S. to foreign IC manufacturers endangers the security of sensitive and classified IP information embedded in chip design. It greatly expands the possibility that harmful software code, embedded Trojan horse attacks, or other unauthorized design inclusions could appear in unclassified integrated circuits used in military and security applications. If offshore IC fabrication migration continues, the DoD and U.S. Intelligence Community potentially could be denied access to ICs and the security-assured functionality of advanced semiconductors, via foreign export restrictions, when these components are essential for U.S. national defense advantage.[62]

Modern ICs are exceedingly complex, yet changes in a small number of transistor gates can cause dramatic changes and degrade security. Past security integrity was created by limiting classified domestically fabricated ICs to onshore fabrication facilities, through in-depth employee security clearance procedures, and through background verification checks of employees. This same approach is not possible with foreign manufactured ICs, but the need remains to verify compliance of the design software, the design IP, and the device functionality. DARPA technology experts highlight the need to protect both application specific integrated circuits (ASICs) and field programmable gate arrays (FPGA). For example, if a malicious circuit were injected via software, the need exists to detect the modification as well as reject the component from DoD and Homeland Security products. DARPA is working to develop a rapid inspection system and validate the trustworthiness of part functionality under their new Trusted IC program. Despite these efforts, a security gap from offshore fabrication will exist as one cannot test-in security features or inspect quality into components.

An additional value-added source of trusted DoD components is the Defense Microelectronics Activity (DMEA), a center for microelectronics technology, acquisition support, parts transformation and technical support. DMEA includes highly-specialized engineering facilities and microelectronic engineers that work in close partnership with the major defense contractors and the semiconductor industry to provide support for fielded systems across all U.S. military organizations. DMEA further serves as a technology partner to military program managers and engineering liaison to defense contractors in order to provide and support the most effective microelectronics technologies available through the commercial sector. DMEA plays a critical role as the sole source microelectronic part certification. DMEA has one-of-a-kind technological capabilities and highly specialized engineering expertise to design, prototype and test new microelectronic components and systems. Besides managing current technology, DMEA also manages obsolete microelectronics. This involves continual active monitoring of a system's parts to stay ahead of the obsolescence curve and to plan ahead for mitigation activities. DMEA avoids strictly reactive obsolescence mitigation activities by

exploring alternatives that are more cost-effective and schedule-responsive. When parts are unprocurable, DMEA has the capability to produce limited quantities of original parts.[63]

Offshore Fab Recommendations for the Future. Three key recommendations should be considered. First, the impacts of outsourcing must be understood and factored into policy; the key strategic issue associated with offshore fabrication is potential loss of industry leadership in semiconductor manufacturing and related national security issues. Competitive fabrication technology centers and knowledge are necessary for the nation's economic vitality and national security. Second, the effects of outsourcing on vital security requirements, such as those needed for crucial Defense and Homeland Security must be understood and managed. The DoD faces potential hostile IC supply dilemmas due to the continued offshoring of fabrication facilities. As production moves offshore, research and development, design capabilities, and tooling have been relocated as well. Many foreign skilled scientists and engineers are moving to overseas locations for increasingly attractive opportunities. Few fabrication facilities can be relied upon to produce trusted, classified national security microelectronics components for crucial DoD development programs, and no roadmap or overall vision exists to ensure U.S. strategic semiconductor leadership. Finally, government-supported fiscal and policy incentives must be considered and implemented to ensure continued U.S. semiconductor industry technology leadership.

Are Semiconductors a National Priority?

The Importance of Semiconductor Leadership. It is of tremendous national importance for the United States to maintain a leadership role in the semiconductor industry for two primary reasons. The first reason is economic and the second is national defense. Technology leadership has been the foundation of American economic success through growth, job creation, and productivity. This leadership has allowed American workers to rapidly create, manufacture, and market innovative products despite strong competition in global markets. Enhanced productivity has generated high wages and unsurpassed living standards within the U.S relative to the rest of the world. The semiconductor industry is an important contributor to the U.S. economy in that it is the second largest U.S. export industry behind aircraft, with total exports of $52 billion.[64]

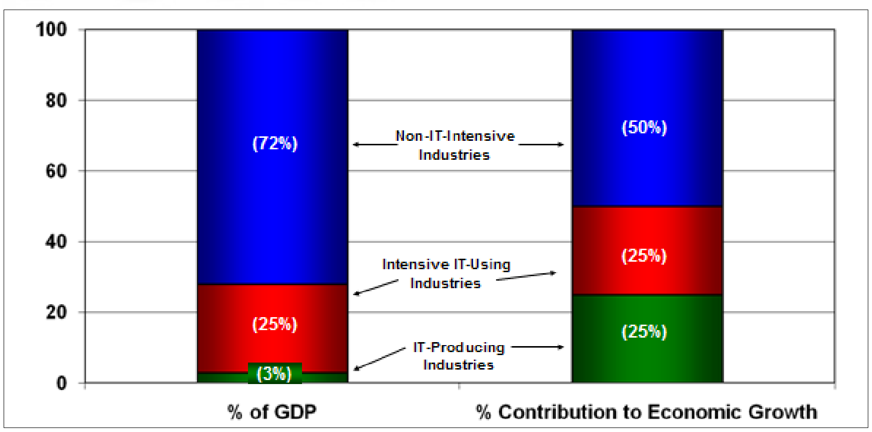

Figure 5: IT Industry's Contribution to Economic Growth

The Semiconductor industry is an engine that powers economic growth; the industry alone employs 232,000 people in the United States in well-paying jobs and generates revenue of more than $118 billion annually.[65] Semiconductors are an enabling technology that not only allows the Internet and information technology to function, but also enables

productivity increases in services, manufacturing, medical, and agricultural industries.[66] **Figure 5** shows that while Information Technology producing industries are only 3% of GDP, they generate much more than their share of economic growth relative to non-IT industries.[67]

Beyond economics, semiconductors are vital to America's national defense. The U.S. has long relied on technology to maintain a military advantage over its enemies and has generally adopted forces founded on technological vice numerical superiority. The importance of cutting-edge electronics cannot be overstated given America's Warfighting doctrine that relies heavily on high-quality, high-technology weapon systems such as AEGIS cruisers, F-22 Fighters, and the "digitized" M1E3 tank. The critical role of microchips in U.S. weapons, communications, and intelligence platforms make maintaining a strong domestic semiconductor industry of strategic value. Given the reliance of the U.S. military on semiconductors, the U.S. must maintain control over development along with life-cycle maintenance and repair of its high technology systems. A robust domestic semiconductor industry insulates the U.S. from the effects of economic shock and disruption, while at the same time enhancing the ability to respond to surge and mobilization requirements. Laser guided weapons and stealth technology reduce a typical first strike package from 132 crewmembers onboard 91 aircraft including tankers, air defense, suppression, escort, and strike aircraft down to two aircraft, a tanker and stealth bomber, with six crewmen.[68] This type of dramatic reduction in aircraft and personnel translated into huge cost savings with fewer lives placed at risk. Collateral damage is also greatly reduced or eliminated, which translates into increased political capital. U.S. military dominance is only possible through the technological superiority driven by semiconductors.

Retaining Semiconductor Leadership is Critical. The next 50 years will be very different from the last 50. There will be intense competition for resources around the globe coupled with rapid technological advances. There are shifting patterns of wealth, global leadership, and the proliferation of weapons and military forces. Electronics will remain a pivotal technology for national security, the economy, and world leadership, providing an edge on the battlefield, in the business community, and on the global stage. Losing this edge translates into reduced operational flexibility, dramatically higher casualty rates, significantly higher costs, longer, more costly military engagements, and diminished global status. To allow the rapid erosion of the U.S. lead in electronics would be devastating to the U.S. military, economic, and leadership position in the world. Electronics and the semiconductor industry must once again become a national priority. The next National Security Strategy must list the electronics industry as a key national priority. The electronics industry is one clear path to a better future for Americans, contributing to security, growth, and welfare. Electronics must become a national priority for the U.S. to continue its economic growth, dominance of the battlefield, retain its global leadership position.

GOVERNMENT GOALS AND ROLE

Goals and the Role of Government

The proper role for government regarding protectionism, specific industry support, and government regulation of markets remains controversial in a free market economy. In the electronics industry, this issue is shaped by the fact that competitor governments have chosen to intervene in the global free market through government incentives and in some cases outright direct cash aid to foreign semiconductor companies.[69] Without comparable incentives, U.S. companies are forced to compete on an uneven playing field, rendering them at an economic disadvantage which ultimately leads to an unsustainable financial position. In the electronics industry, the government should take an active role to lubricate the free market process with initiatives that contribute to the greater economic good and promote national defense. Government policy can generate a market *pull* for technologies that are already developed and close to commercialization. At the same time, concerted public and private investments in research and development can *push* the process of innovation, thereby expanding the menu of technology options that will be available in the future.[70]

Policy Recommendations

Near-Term Goals

The U.S. must reverse the downsizing of its innovation-related analytical and policy making infrastructure that occurred over the past two decades. The Department of Defense should continue its efforts to develop a broad strategy to deal with the growing migration of manufacturing and assembly offshore. This policy must also address requirements during periods of surge and mobilization. Congress should enact legislation to make the R&D tax credit permanent. This would enhance the credit's incentive value by allowing companies to program the full benefits into their long-term financial and R&D strategies. Doing so will enhance the ability of U.S. industry to make a sustained commitment to long-term, high-cost research.[71] The R&D tax credit should also be strengthened by increasing the new alternative simplified credit rate from 12% to 20%. These changes would help "level the playing field" with foreign competitors and serve as a powerful incentive for companies to locate more R&D in the U.S., reversing the current trend.[72] Another incentive is to change semiconductor equipment depreciation schedules because current tax laws depreciate semiconductor manufacturing equipment over five years even though the economic life of this equipment is typically only three years.[73] Changing to three year depreciation more closely aligns U.S. policy with foreign country competitors and current equipment replacement cycles.[74] The Department of Defense should continue work to expand the trusted foundry program in order to fully develop trusted suppliers for integrated circuits, trusted foundries for sensitive applications, and a documented, well-maintained supply offshore supply chain for other applications.[75] DoD should also conduct research to better test processes that will ensure that defense chips obtained from foreign sources are free from malicious logic. Given the criticality of its role in sourcing DoD microelectronics, recommend maintaining current funding for the Defense Microelectronics Activity (DMEA) commensurate with demand. In addition, it is imperative that DMEA representatives maintain close coordination with DoD logisticians and Project Managers to ensure that DoD takes full advantage of DMEA capabilities.

Congress should appropriate the resources outlined in the America COMPETES Act to see The President's America Competes Initiative to fruition. In the short term this involves restoring

2008 funding through a supplemental appropriation of at least $300 million to the Department of Energy Office of Science and $200 million to the National Science Foundation to address the most acute shortages in terms of losses in jobs, facility closures and research.[76] 2008 supplemental funding should also restore $20 million in support of the Focus Center Research Program (FCRP,) which marries government and industry funds to discover solutions to problems that must be overcome for continued semiconductor advancement. This program focuses on mid to long term research at 33 U.S. universities.[77] Finally, in FY09, the President should ask for, and the Congress should fund, all of the education programs enacted in the America COMPETES Act. Scholarships and partnerships to train STEM teachers are currently underfunded by more than $160 million.[78]

Mid-Term Goals

As it becomes more difficult to leverage scaling to generate circuit performance gains, innovation and the quality of R&D are becoming increasingly important. A mid-term R&D challenge is to bridge the so-called "valley of death" between basic research and market application.[79] The National Institute of Standards and Technology (NIST) Technology Innovation Program (TIP) will help mitigate the valley of death. FY2009 funding currently absent from the President's proposed budget should be restored and the program should continue to receive funding in the out years. Over the mid-term, full funding should continue for the National Science Foundation with 7% annual increases to place funding on a glide path to meet increases authorized in the National Science Foundation Authorization Act of 2002.[80] Full funding should also continue for Focus Center Research Program and the NIST Lab budget.

Field studies in China and Taiwan identified that the Chinese national, regional, and city governments are aggressively courting the semiconductor industry with a wide array of economic incentives including the procurement of a $3B fab for Semiconductor Manufacturing International Corporation (SMIC). Chinese and Taiwanese efforts are focused on building innovation ecosystems with incentives that co-locate and align the efforts of education institutions, research and development, and manufacturing. While this creates an uneven playing field given the current limited incentives from the U.S. government, China's incentives do not violate international law or World Trade Organization norms. To maintain the U.S. semiconductor industry, federal, state and local government should continue to utilize tax holidays, research partnerships, and infrastructure contributions to entice companies to locate facilities in the U.S. One excellent model is Micron's partnership with the State and county in Prince William County, Virginia; a second is the State of New York's incentive program in support of IBM's in-state operations. Both of these examples also leverage research partnerships with local universities and industry partners.

Human capital development deserves considerable policy attention. Immigration reform is necessary to attract and retain the highly skilled workers that underpin an economy of technological innovation. Many Ph.D. candidates are educated in the U.S. but are unable to stay due to shortcomings in U.S. immigration policy.[81] The U.S. should reassess the current H-1B visa caps and make more visas available for highly educated and highly skilled immigrants. The H-1B program is often used as a stepping stone toward the attainment of an employment-based green card. Unfortunately, the limited number of available cards and huge backlog (of up to five years or more) remains a barrier to attracting the best talent in the global labor pool.[82] One solution is to create a new foreign student visa category to allow STEM degree holders who have a job offer to transition directly from student visas to green cards.[83]

Long-Term Goals

U.S. policy must also address long-term strategies to protect U.S. military technological advantages and enhance the nation's ability to compete in the semiconductor industry. U.S. semiconductor companies must be global exporters in order to survive. Unfortunately, U.S. export controls stifle American companies' entry into some global markets. One opportunity for improvement is to accelerate the interagency approval process from its current several months to weeks.[84] Faster export approval will provide more agility for U.S. companies as they compete in shorter product cycles. The U.S. government, World Trade Organization, and global businesses must also pressure China to allow equal access for U.S. companies in China's burgeoning domestic consumer and assembly market and guard against other discriminatory practices worldwide. Another critical long-term issue is protection of intellectual property. The globalization of the semiconductor business requires a global approach to Intellectual Property (IP) management.[85] The U.S. should use diplomatic and trade forums to strengthen IP protection laws and encourage aggressive enforcement and penalties throughout the world. Field studies in China show that the Chinese government is making initial efforts to improve IP. While IP remains a concern for foreign companies in China, there is no evidence that IP concerns are limiting foreign research, development, or manufacturing in China. Chinese government efforts to improve IP protection are evident in both education programs and in increased legal statute and litigation avenues available to companies.

Over the long term, the Federal government should take a broad role of setting the national agenda, funding research, supporting the development and dissemination of best practices, collecting and disseminating economic data, and encouraging multi-state collaboration.[86] The U.S. should have a national strategic plan similar to China's well-defined 5 and 15 year plan for their semiconductor industry. In addition, the U.S. should maintain its leadership role in standards-setting, leveraging the talents of NIST while monitoring the development of worldwide and national standards to ensure that standards are not used as a way to discriminate against U.S. products.[87] Finally, long-term funding of America COMPETES Act K-12 education initiatives is critical to growing the next generation of American researchers and scientists.

CONCLUSION

The electronics industry is critical to American prosperity and national security. It remains the United States' second largest export industry, continuing to provide high-paying, quality jobs for over a quarter of a million Americans. Among all industries, the electronics industry is exceptional because it is the key industry that enables all others. Since the U.S. invention of the integrated circuit, every facet of the American economy has been touched by the rapid evolution of the semiconductor, and American industry has benefitted tremendously – either through the rapid productivity gains enabled by the electronics industry, or through an entirely new knowledge-based economy that the electronics industry created. The industry also conferred considerable advantage to America's armed forces by providing decisive technical superiority on the battlefield.

Because it hosted the invention of the integrated circuit, the United States enjoyed significant initial competitive advantage; the invention of the integrated circuit 50 years ago culminated in the overwhelming success of industry giants like Intel and Texas Instruments, and resulted in unique "innovative IC ecosystems" in places like Silicon Valley, California. These ecosystems continued the cycle of world-class U.S. electronics industry excellence by partnering world-class academic institutions with venture capital and IC design and production companies. This partnering allowed cutting-edge technologies to move quickly from academia to market success.

However, today the paradigm has changed. The global economy has driven tremendous competition for every activity along the semiconductor value chain, and many foreign companies today have emerged as leaders in their segment of IC production. Government incentive policies in Asia have pulled much of the IC fabrication segment overseas, and additional high-end segments of the IC value chain are following. Taiwan and China are replicating the original U.S. innovative IC ecosystem, providing them tremendous competitive industry advantage and setting them up for potential future industry leadership.

The United States is at a critical turning point. In order to reverse its rapidly eroding lead in the electronics industry, it must immediately adopt several proactive government policies. These include fully resourcing the America COMPETES Act in order to support basic semiconductor science research, and increased investment in the education of the next-generation of American electronics industry leaders. The U.S. must increase funding for DoD basic research accounts. DoD has historically been the largest federal funder of the disciplines necessary for advances in electronics and semiconductor technology, including electrical, mechanical and materials engineering and computer sciences. It must level the global playing field by offering comparable government incentives that are currently pulling the electronics industry to Asia, including offering tax incentives to IC manufacturers that locate in the U.S., making IC industry research and development tax credits permanent, and reducing the depreciation schedule for expensive IC production equipment. In order to retain the best and brightest global IC talent, the U.S. should modify its current H-1B visa program to make more visas available for highly-educated foreign students who want to stay in the U.S. and work, but currently cannot. Finally, the U.S. should use diplomatic and trade forums to strengthen world-wide IC intellectual property protection, and ensure that U.S. electronics suppliers have fair and open access to foreign markets.

For the past 50 years, America's economic prosperity and military superiority were largely driven by its lead in the electronics industry. That lead is dramatically slipping away. In order to guarantee success for America's next generation, the time to act is now.

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